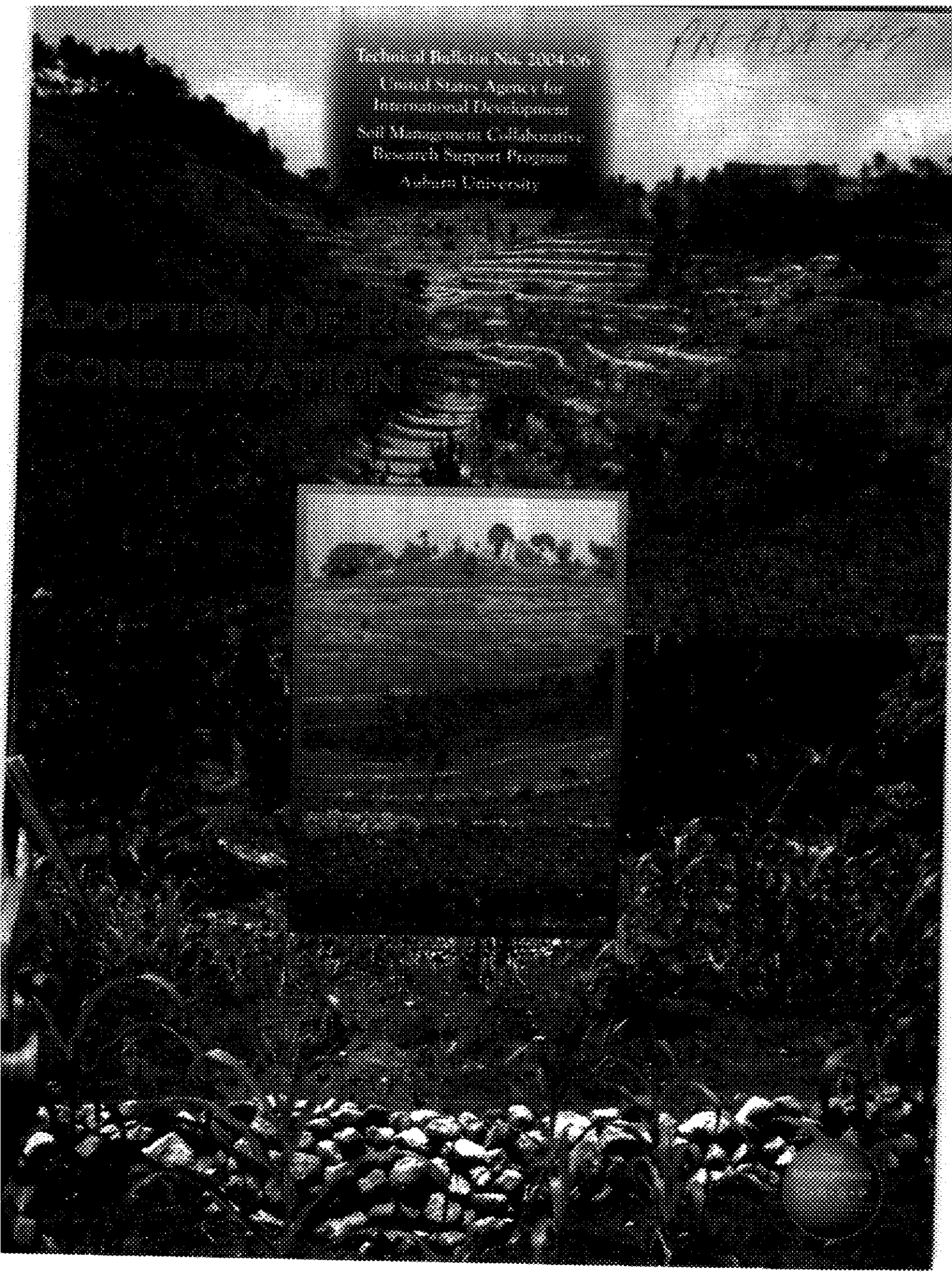
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Adoption of Rock Walls as a Soil Conservation Structure in Haiti

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INTRODUCTION

Land degradation has been identified as one of the most serious ecological, environmental, and economic problems facing the Haitian society today. One particular problem associated with land use is soil erosion. Throughout the 19th century, demographic, socioeconomic, and market pressures forced Haitian farmers to clear forest areas in order to grow annual crops on steep and fragile lands (Bellande et al. 1979). Crop intensification and continuous cultivation of steep lands without supplementary use of conservation practices have accelerated the rate of soil loss in Haiti. In 1990, it was estimated that Haiti was losing 36 million tons of soil each year (Association Internationale de Dévelopement 1990).

Early efforts to restrict environmental damage emanating from soil erosion have focused on mechanical structures, such as rock walls and gully plugs. Since the early 1940s, government and non-governmental agencies have launched several watershed management projects using rock walls as the principal soil conservation practice (Regis 1999). In case studies on soil conservation technology in Haiti, Lea (1996) found that the installation of rock walls on peasant farms was profitable. This technique yielded internal rates of return of up to 75 percent, making investment in this practice relatively attractive.

Despite the effectiveness of this technique in controlling erosion and the high return on investment, its diffusion throughout Haiti is limited. When the practice is adopted, the structures are not adequately maintained, as indicated by Lea (1996). In the search for answers to farmers' reluctance to adopt and manage soil conservation structures in Haiti, especially rock walls, previous studies (Saint-Dic 1981; Jean-Pierre 1984) mainly focused on two major factors: land tenancy and investment costs. They indicated that high capital expenditures for installation of rock walls and the lack of land security discouraged farmers from investing in rock walls, even in areas where rocks are abundant. Since rock walls have been adopted in areas such as Fort-Jacques, legitimate questions may be raised as to what factors play a determinant role in the adoption and management of rock walls in this particular locale. This investigation concentrates on the adoption and management of rock walls in Fort-Jacques. The results presented in this publication are based on a survey conducted on 115 farm households in the Fort-Jacques area between December 1999 and January 2000.

LOCATION OF THE STUDY

Physical characteristics

The research was conducted in Fort-Jacques (Figure 1), a hilly area located about 30 miles (48.3 km) southeast of Port-au-Prince, the capital of Haiti (18°13' N, 78°W).

Since the 1940s, farmers in this zone have witnessed the implementation of soil conservation projects, from reforestation to rock wall installation (Murray 1979). The elevation of the zone varies from 900 to 1,400 meters above sea level, and has a mean annual temperature of 22°C. The average annual rainfall is about 2,000 millimeters distributed in a bimodal pattern, with rain occurring from February to May and from August to November. At this high elevation with steep slopes, rock walls are essential for sustainable agricultural production. The land in this area was originally covered with forest trees, but population growth and economic pressure have led to vast deforestation since the 19th century (communication with area's elders). Today, the area is partially uncovered with an abundance of rocks distributed over the landscape and slopes varying from 10 to 60 percent.

Agricultural production systems

The characteristics of the farms in Fort-Jacques are typical of the general situation found in Haiti. Farmers in this zone operate an average of three plots located at various distances from their homes. Farmers interviewed operate between one to six plots. The average size of a farm is 0.70 hectares (ha) within the range of 0.04 and 4.26 ha (Table 1). Seventy-seven percent of the farmers operate less than 1.0 ha, 19 percent have between 1.0 and 2.5 ha, and only 4.0 percent operate more than 2.5 ha of land.

TABLE 1. DISTRIBUTION OF FARM SIZE IN FORT-JACQUES, HAITI, 1999

Size	Mean	Percentage of farms
Average size	0.70 ha	
Less than 1 ha		77
1 to 2.5 ha		19
More than 2.5 ha		4

Haitian farmers are usually involved in a set of tenancy relationships that prevent them from implementing important long-term investments on the land. Farmers in Fort-Jacques operate plots under different land tenure arrangements, including direct ownership, rent, inheritance, and sharecropping. For each farm, we define a security index, indicating the degree to which farmers own and control land resources in Fort-Jacques. This index is calculated by dividing the number of hectares directly owned by the farmers by the total area (ha) of land operated. In this region, the average index of land security is 0.19, indicating that farmers in Fort-Jacques have limited control over the land they operate.

Land tenure, though a critical factor in farm investment and development, is precarious in the study area. Two major factors explain the land situation in Fort-Jacques. First, demographic pressure has pushed the use of land beyond the limit of its sustainable capacity. Under the Haitian inheritance system, all children receive equal shares of their parents' land. Plots previously operated by one farmer may now belong to several heirs. Legal division of land is almost impossible in many cases in Fort-Jacques. The second aspect of the situation concerns the importance of the land market in the zone. There is an impressively vigorous land market in this area where farmers seem to be sellers rather than buyers.

For decades, wealthy people have been buying mountain lands with the intention of creating vacation homes (Murray 1979). In recent years a shortage of housing in urban areas and the high risk of

investment in other sectors of the economy led many city dwellers to invest in land to build houses. Hence, land values have increased substantially during the last decade. Even though investment in agriculture is relatively attractive in Fort-Jacques, farmers have sold their lands at significant prices in order to fund the migration of family members. In many cases, the former owner of the land continues to live on the plot as a manager until the new owner decides to build a house. Farmers' access to land in the Fort-Jacques area emanates from several relationships that lead to different types of insecurity (Murray). Establishment and management of soil conservation practices in Fort-Jacques may be influenced by the degree of land tenure security.

Due to the environmental conditions of the zone, farmers produce a variety of higher value crops including vegetables, grain, and tubers. Those crops include cabbage, carrots, tomatoes, potatoes, onions, beans, lettuce, leeks, and other vine and leafy vegetables. On each small holding, those crops are produced in limited quantities. Farmers usually intercrop the species in order to have vegetables for sale all year round. The farming system in the area is highly intensive. The fallow period lasts only from one to three months. Because of this short period of fallow, the maintenance of soil fertility is through the addition of chemical fertilizers. Farmers make intensive use of fertilizers that are appropriate for vegetable production. They also use pesticides to limit damage caused by insects and other pests.

Animal production also plays an important role in the peasant economy of Fort-Jacques. Pig farming is the most common form of animal husbandry in the area (Figure 2). The average number of pigs on a farm is 1.45. Seventy percent of the farms own at least one pig. Following pigs, cattle production comes in second place. Approximately 58 percent of the farms raise cattle; the number of cattle on a farm averages 0.86. The importance of other types of animals on the farms is less significant.

Socioeconomic characteristics of the households

Information on the characteristics of the households is presented in Table 2. The average age of all farmers interviewed was roughly 51 years, varying from 25 to 90 years. Forty-eight percent of all interviewees were between 25 and 50 years old. Approximately 36 percent of all interviewees were between 51 to 65 years old, while only 16 percent were older than 65 years.

Seventy percent of all respondents declared that they were married. Respondents with the status of single and common-law union represent 15 percent each. In terms of level of education, three categories of farmers are identified in the Fort-Jacques area: farmers with no formal education, those who attended primary school, and those who attended high school. The majority of farmers (50 percent) interviewed had no formal education. Forty-one percent of farmers attended primary school, only 9.0 percent attended secondary school.

Despite a relatively high level of illiteracy in the zone, 21 percent of the farmers who responded declare they have received training in soil conservation from a nearby Baptist Missionary organization. Soil conservation projects usually operate through local organizations. Community organizations have been extensively used in the past for building rural roads and rock walls. In the Fort-Jacques area, of those who declared that they participated in local organizations, 78 percent are members of agricultural cooperatives. They are more interested in organizations that provide agricultural inputs at relatively low costs.

Households participating in the survey had several members who were engaged in various agricultural and non-agricultural occupations. The average household contains seven individuals. This situation places pressure on the households' limited resources. Land is scarce, and several people depend upon a small piece of land for survival. Sixty-five percent of all households have more than five people. Haitian farmers primarily are dependent on family labor. Labor availability for farming appears to be a critical fac-

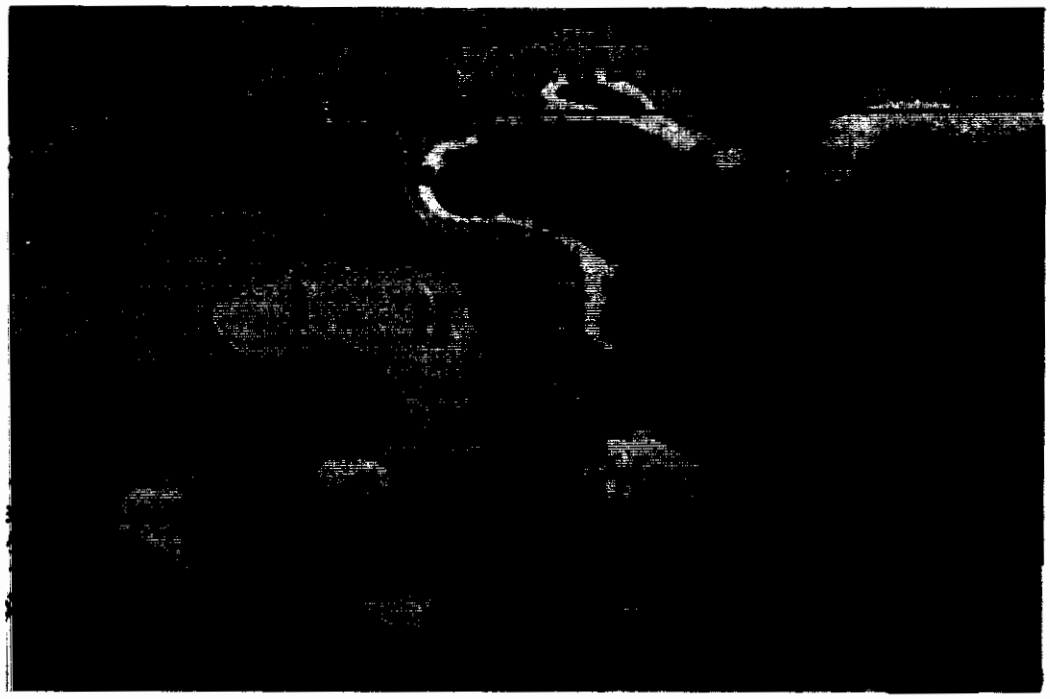
tor during peak seasons. The average number of workers available per ha in a household in Fort-Jacques was about 14. Sixty-four percent of all farms had more than five workers per hectare. In a situation where land is scarce, the farms are unable to absorb the number of workers available in the household. Therefore, many people migrate periodically to find non-farm jobs in Port-au-Prince and other nearby cities.

TABLE 2. SELECTED SOCIO-DEMOGRAPHIC CHARACTERISTICS OF FARMERS IN FORT-JACQUES, HAITI, 1999

	Mean	% of respondents
Age	51 years	
25 to 50 years		48
51 to 65 years		36
Above 65 years		16
Marital status		
Married		70
Single		15
Common law union		15
Education		
No schooling		50
Primary school		41
Secondary school		9

Young children go to school either in the community or in nearby villages. Seventy-eight percent of households in Fort-Jacques have children in school. Each household in Fort-Jacques participating in the survey had an average of three children in school. Other family members had off-farm jobs that provided them with additional revenues. Forty-two percent of heads-of household interviewed had off-farm employment; approximately 30 percent of households had a family member employed off the farm. These off-farm activities include mainly masonry, small commerce, and employment as casual workers.

All the activities developed by the households are aimed at increasing the families' income, and consequently improving their standard of living. The level of income of the household is relatively higher in Fort-Jacques than in other zones where farmers grow predominantly subsistence crops. Farmers obtain their income from different sources including crop production, livestock and off-farm activities. The mean income from different sources of the selected households in Fort-Jacques is 12,099 gourdes (US $1=20 gourdes). Marketing of crops remains the major source of income for farmers in the study area; however, off-farm activities make a significant contribution to the total household income. Agricultural income, which includes crop and livestock revenues, represents about 53 percent of the total income (Figure 3). Revenues from activities other than farming make up 47 percent of the household total revenue. The average level of per capita income of households in Fort-Jacques is 2,041 gourdes per year. It varies from 63 gourdes to 13,025 gourdes, with 44 percent of households having between 1,000 and 3,000 gourdes.



■ Fort-Jacques

Figure 1. Location of the Study Area

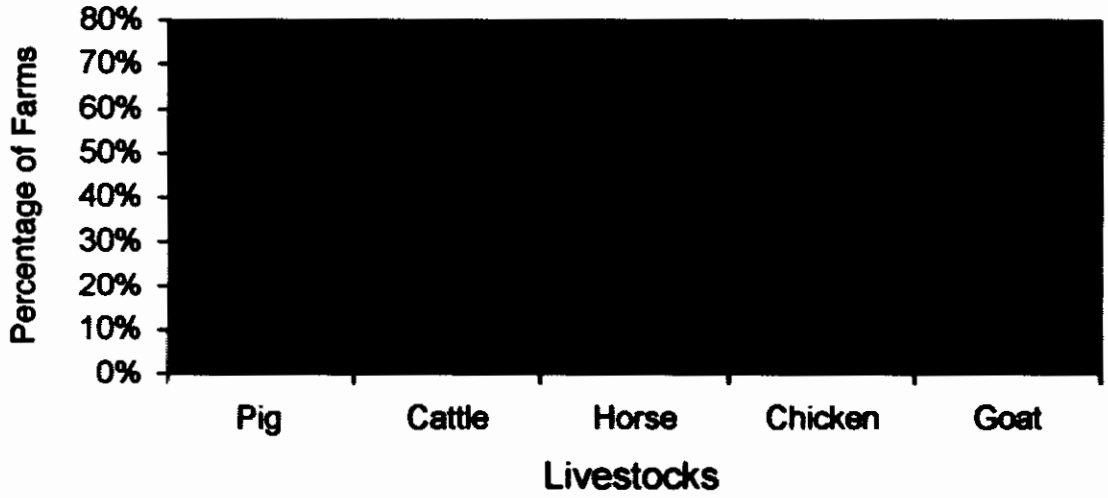


Figure 2. Distribution of Livestock on the Farms in Fort Jacques, Haiti, 1999.

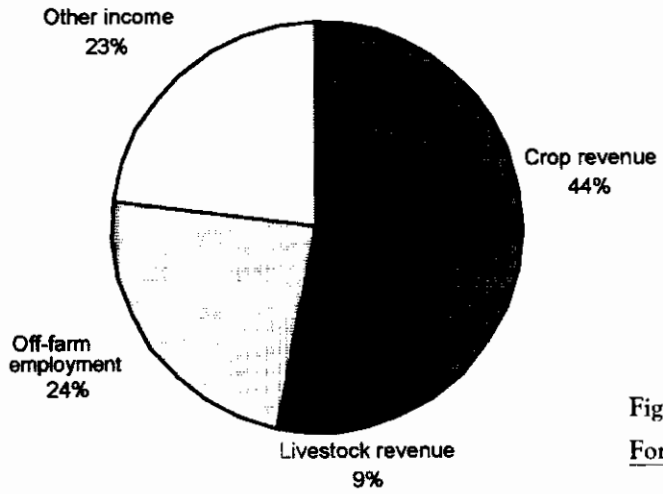


Figure 3. Distribution of Household Income in Fort-Jacques, Haiti, 1999.

Figure 4. Example of Rock Walls in Haiti.

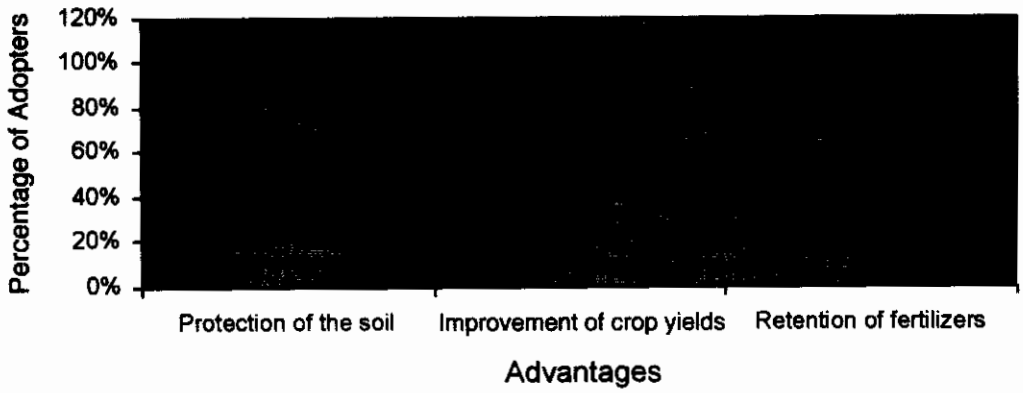


Figure 5. Stated Advantages of Rock Walls by Adopters.

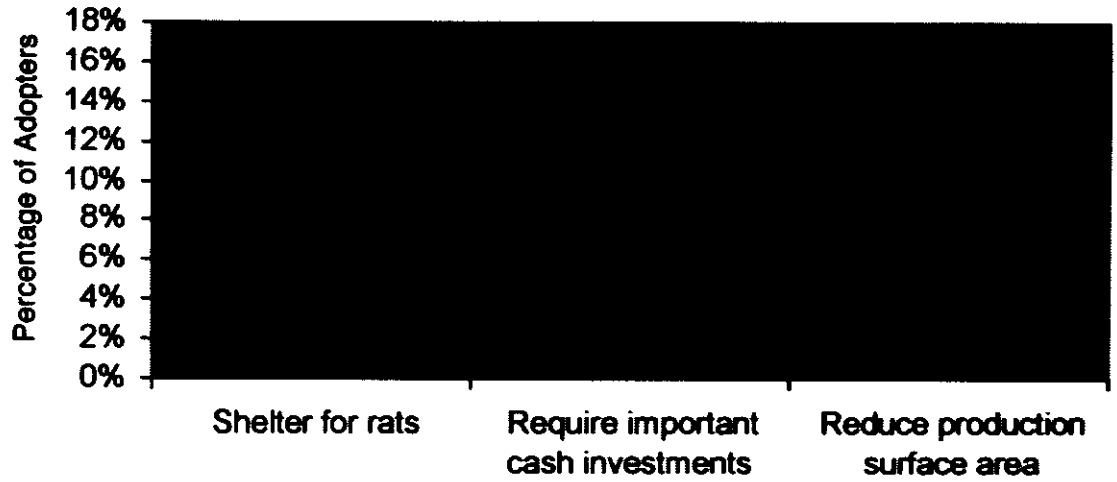


Figure 6. Stated Disadvantages of Rock Walls by Adopters.

Figure 7. Ownership Status of Rock Wall Treated Plots.

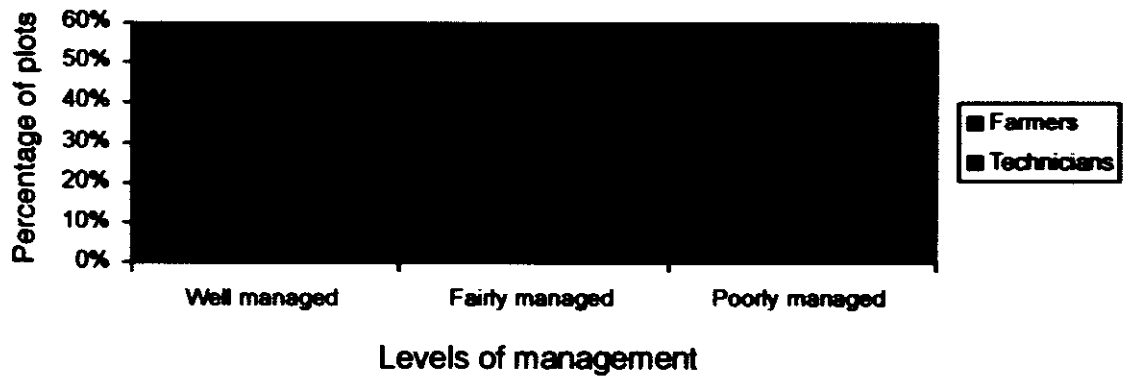


Figure 8. Evaluation of Rock Wall Structures by Farmers and Technicians.

DIFFUSION OF ROCK WALLS

Attributes of rock walls

Rock retention walls (Figure 4) are structures built along the contour of slopes with the purpose of slowing down and diverting rainfall, controlling erosion of steep lands, and forming a natural terrace over time (Toness et al. 1998). This technique is particularly effective at reducing soil loss (Hallsworth 1987; Wiggins 1981). It requires less maintenance than other techniques, such as terraces, and little knowledge of engineering is needed to install them (Williams and Walter 1988). Studies conducted in other tropical countries have indicated several benefits of rock walls. In a study in Honduras, Lopez-Pereira et al. (1994) reported that rock walls increase water retention and reduce the risk of unprofitable fertilizer application. Significant increases in crop yields and positive effects of rock walls on farmers' income are also reported, especially when improved seed and fertilizers are used (Lopez-Pereira et al. 1994; Santos et al. 2000). Nevertheless, the rock wall technique is labor intensive and necessitates important investments (Toness et al. 1998).

Rock walls have been used in Haiti for decades; however, their adoption is limited, and the management of the structures is often less than satisfying. Lea (1996) reported positive changes in grain yields ranging from 22 to 57 percent with the installation of rock walls. Lea (2000) reported an adoption rate of rock walls of 29 percent among farmers in different areas in Haiti. Nevertheless, the extension of this soil conservation practice throughout the country is relatively limited. In short, the lack of adoption of rock walls and a low level of maintenance of existing structures remain serious barriers in the effort to reduce erosion effects in different areas.

Farmers' adoption of rock walls

Rock walls are among the oldest soil conservation practices in use in Fort-Jacques. They have been placed in the zone since the 1940s (Murray). All farmers interviewed are aware of the use of rock walls as a soil conservation practice. The present generation has learned from their parents who witnessed several soil conservation projects and have participated in community work. The importance of rock walls as a soil conservation measure is clearly stressed by all farmers in Fort-Jacques. They all indicated that rock walls are beneficial to the environment. They pointed out that production of vegetables is nearly impossible on plots without soil conservation structures. Thus, rock walls are an important element of the farming system in the area. Fifty-nine percent of farmers interviewed in Fort-Jacques have rock walls on at least one plot. Some of them have built the structures without any external assistance. However, a number of farmers encountered existing rock walls on the farm at the commencement of their present farming activities. A particular aspect of the rock walls in Fort-Jacques is that they are not built according to technical specifications. The walls were not placed along contour lines, as is often recommended by technical agents. In many cases, the rock walls are piles of rocks rather than tightly fitted structures. Nevertheless, farmers declared that the structures reduced erosion by preventing the soil from washing away from their plots.

Farmers in Fort-Jacques have identified several advantages of rock walls (Figure 5), including protection of topsoil (100 percent), improvement of crop yields (43 percent) and retention of fertilizers (70 percent). Nevertheless, they also underlined some disadvantages (Figure 6). Sixteen percent of the farmers mentioned that the walls are shelters for rats that destroy plants. They also indicated that the walls reduce the space available for crops, limit possibilities for animal grazing, and require important cash investments for establishment and maintenance.

Even though farmers recognize that rock walls reduce production surface area, they indicate that the plots are difficult to farm when rocks are scattered all over the field. Thus, building rock walls not only permits erosion control, but also facilitates field operations.

Table 3 presents some characteristics of rock wall-treated plots in Fort-Jacques. The number of years since the implementation of the rock walls on farmers' plots varied from one to 30. According to the respondents, the structures observed in Fort-Jacques are, on average, 10 years old. Thirty-seven percent of the established structures are more than 10 years old, while 24 percent are between five and ten years. These values show that the establishment of rock walls are a familiar practice in the research area.

TABLE 3. CHARACTERISTICS OF ROCK WALL TREATED PLOTS

Item	Unit	Mean	Minimum	Maximum
Size of plot	Hectare	0.69	0.02	1.29
Distance from home	Minute	10	1	40
Slope	Percent	28	12	60
Years with rock walls	Number	10	1	30

The size of the plots, on which rock walls are established, ranges from 0.04 to 0.65 ha; the average size of a treated plot is 0.26 ha. Sixty percent of the plots measure less than 0.25 ha, and 27 percent have a size between 0.25 ha and 0.50 ha. The tenure of these plots varies from one farm to another. Inheritance is the most common form of land transfer in the Fort-Jacques area (Figure 7). Fifty-three percent of all farmers interviewed declare that they inherit the plots with rock walls. The percent of purchased plots represent 19 percent; rented, managed, and half-lease holdings represent 13 percent, 13 percent, and 2 percent, respectively.

The time required to walk from a farmer's home to a treated plot averages 10 minutes. The distance varies in time from one to 40 minutes, with 45 percent of the plots being between five and ten minutes away. Thirty-seven percent of the plots are located at less than five minutes from the farmers' home, while only 18 percent are found at more than 10 minutes. Rock walls in Fort-Jacques are established on plots with average slopes of 28 percent. The slope of all evaluated plots varies from 10 to 60 percent. The majority of the plots (71 percent) have slopes between 12 and 35 percent. Twenty-five percent of the plots have slopes between 36 and 45 percent. Under such conditions, in which land considered as non-arable is being used for agricultural production, erosion becomes a serious problem, especially when rainfall is heavy.

Management of rock wall structures

Management of established rock wall structures is an important aspect of adoption of soil conservation technologies. The efficiency of a structure depends upon its level of management. All farmers interviewed in Fort-Jacques acknowledged that they maintained the rock walls implemented on their plots. Two major activities are undertaken to maintain the structures: repair of breaches by arranging rocks in the walls, and increase in the height of the walls when there is over-accumulation of soil behind the walls. Considering the nature of this soil conservation practice, farmers stated that it was not necessary to frequently maintain the rock walls. However, 70 percent of the farmers interviewed declared that they manage the structures once a year. Observations during the survey period, revealed a lack of maintenance of rock wall structures on several plots. In a number of cases, the walls were broken down and the rocks were scattered on plots limiting the space available to grow crops. A practice observed in the zone is that some farmers let the soil accumulate on the wall; then rebuild the structures a little farther down the slope until they create a relatively flat surface to grow vegetables.

Rock walls established on farmers' plots in Fort-Jacques were managed differently from one plot to another. A number of questions were included in the survey to determine how well structures established on farmers' plots were managed. When asked to evaluate the management of the structures implemented on their plot, farmers state that 41 percent were well managed, 48 percent and 10 percent of the structures were fairly, and poorly managed, respectively. However, results from enumerators' evaluation indicated different outcomes. Enumerators' evaluation of the structures showed that 25 percent of all structures were well managed, 53 percent fairly well and 22 percent of the treated plots were poorly managed (Figure 8). It is obvious that there exists a difference in the distribution of the level of management of the rock walls among evaluations. However, all evaluations indicated that the level of management of the structures was predominantly average, followed by good and poor, successively.

Management of rock wall structures does not seem to be the first priority of farmers in Fort-Jacques. The most important thing is how to keep growing vegetables without losing the fertilizers due to leaching and soil loss. Tenure arrangement of the treated plots does not appear to play an important role in all instances in farmers' decision to invest in rock walls. However, it may be important in particular cases. For instance, in discussion with farmers, a number of them mentioned that they do not maintain the structures because they do not know when the owner of the plot will reclaim them. As mentioned earlier, upon selling the plot, a number of farmers serve as managers until the current owner decides to build a house. That can take three to five years. The instability of prices of vegetables on local markets, and the relatively high prices of the agricultural inputs, such as improved seeds, fertilizers and pesticides, often discourage or prevent them from benefiting from rock wall investments.

Factors influencing adoption of rock walls

Factors influencing farmers' decisions to invest in rock walls in Fort-Jacques were investigated using a logistic regression model. The model is aimed at determining the probability that a farmer will adopt rock walls as a soil conservation measure. The dependent variable is represented by the binary choice of adoption or non-adoption. The dependent variable takes the value of 1, if the farmer is an adopter of rock walls, and 0 otherwise. The independent variables used to estimate the coefficients of the adoption model include farm operator characteristics (age, gender, education level, marital status, membership in local organizations, training in soil and water conservation), farm characteristics (size of farm, index of land tenure security), crop dependency, and household per capita income. The explanatory variables are defined in table 4.

TABLE 4. DEFINITION OF VARIABLES USED IN THE ADOPTION OF ROCK WALLS

Variable	Definition	Expected effect
1. Age	Number of years of the respondent	(-)
2. Gender	1 if respondent is male, 0 otherwise	(+)
3. Marital status	1 if respondent is married, 0 otherwise	?
4. Education level	1 if respondent has a formal education, 0 otherwise	(-)
5. Group membership	1 if respondent is member of a local group, 0 otherwise	(+)
6. Soil conservation training	1 if farmer has a training, 0 otherwise	(+)
7. Per capita income	Annual per capita income of household	(+)
8. Crop dependency	Share of crop revenues in total income	(+)
9. Size of farm	Number of ha of land operated	(+)
10. Security of tenure	Share of owned land out of total operated land	(+)

The findings of the model reported in table 5 indicate that five variables—namely gender, membership in local organization, training in soil conservation practice, size of farm and per capita income - appear to be significant determinants of the adoption of rock walls in Fort-Jacques. Gender also plays a positive and significant role in the adoption of rock walls in the area. The positive influence of this factor implies that male farmers are 5.8 times more likely to invest in rock walls as a soil conservation measure than their female counterparts. The probability of adoption of rock walls increases when the head of household is male. In fact the placement of rock walls is labor and cash intensive. It is considered as a man's job; female farmers will establish rock walls if they can afford the necessary initial investments.

TABLE 5. FACTORS AFFECTING ADOPTION OF ROCK WALLS IN FORT-JACQUES, HAITI

Variables	Coefficients	Standard Error	Odds Ratio
Intercept	-0.79369	1.21399	
Age	-0.0192	0.01777	0.98
Gender (male)	1.6824	0.85906*	5.38
Marital Status	0.40749	0.859	1.5
Group membership	-1.5485	0.5167*	0.21
Training in soil conservation	1.5432	0.6553*	4.68
Size of Farm	-0.71935	0.3822*	0.49
Per capita income	0.00021	0.000122*	1.00
Crop dependency	1.0137	0.7071	2.76

*Significant at α = 10%

Training in soil erosion problems and conservation measures is also an important factor influencing adoption of rock walls in Fort-Jacques. The results suggest that the probability of adopting rock walls as erosion-control measures increases with training. Farmers who receive training in soil conservation, especially rock walls, are 4.7 times more likely to adopt this practice than those who do not. The information collected during the survey indicates that more than 50 percent of farmers in Fort-Jacques have no formal education, but some of them have participated in training sessions on soil conservation practices. It is not essential for a farmer to have a high level of formal schooling to participate in soil conservation training. The training sessions usually increase farmers' awareness of damages caused by erosion and the direct benefits of conservation.

Another factor that has a positive impact on the probability of adopting rock walls in Fort-Jacques is per capita income. In Fort Jacques, past soil conservation projects have helped with the establishment of rock walls on some publicly owned eroded plots. However, the majority of farmers have implemented structures on their plots with their own financial means. The high probability that rock walls will increase crop production provides incentives for investment in such a soil conservation practice. Given the substantial amount of cash required to establish rock walls, the probability of adopting this technique increases as the level of per capita income increases. Crop dependency is a factor that seems to have a positive influence on the probability of adoption of rock walls; but its effect is marginally significant.

Membership in local organizations and size of farm are included in the adoption model of rock walls. Both variables are significant determinants of adoption of rock walls, but they have negative impacts. As size of farms increases by one unit, the probability that farmers will adopt rock walls decreases by 0.49. As mentioned by farmers, rock wall installation is expensive. It is very effective in controlling erosion particularly on sloping plots, but cash is needed for the initial investments. Even though investment in such structures may be profitable in this area, it may be financially difficult to establish large numbers of structures required on a large farm to reduce erosion while ensuring the farm family survival. In addition, it may be difficult to find and transport heavy rocks to conserve large surface areas.

The findings also suggest that membership in local organizations has a significant, but negative impact on the adoption of rock walls. Farmers who participate in local organizations are 0.2 times less likely to adopt rock walls in Fort-Jacques. Originally, strategies to promote rock walls in several locations in Haiti focused on community groups. Farmers interviewed in Fort-Jacques state that not all members benefit from such groups. Given the importance of the structures in the production systems, it is better for an individual farmer to make his own decisions.

In short, various factors play significant roles in the probability of adoption of rock walls in Fort-Jacques. They include personal characteristics of farmers, institutional factors, such as membership in local groups, training in soil conservation, and economic factors such as per capita income and size of farm.

Contribution of rock walls to household income in Fort-Jacques

As mentioned earlier, farmers in the Fort-Jacques area earn income from various sources. However, agriculture remains the main source of earnings. Once a particular technique is adopted, a direct positive effect on agricultural products is often expected. Increasing crop yields ultimately improves the level of income of the adopters. The average level of per capita income in Fort-Jacques is 2,252 gourdes for an adopter of rock walls, and 1,736 for a non-adopter. About 50 percent of adopters have per capita incomes between 1,000 and 3,000 gourdes, while 49 percent of non-adopters have incomes less than 1,000 gourdes (Table 6).

TABLE 6. DISTRIBUTION OF THE ANNUAL PER CAPITA INCOME BY ADOPTERS AND NON-ADOPTERS

	Adopters	**Non-adopters**
	% of farmers	% of farmers
Less than 1000 gourdes	26	49
1000 to 3000 gourdes	50	36
Above 3000 gourdes	24	15

Analysis of variance was used to determine whether adoption and maintenance of rock walls are significant contributors to household revenues in the Fort-Jacques area. Effects of rock walls were analyzed for crop revenues, total agricultural income, total farm income (which includes all sources of earnings), and per capita income.

Results of the analysis reported in Table 7, support the idea that adoption of rock walls positively influences farm family income in Fort-Jacques. Indeed, rock walls significantly and positively influence crop revenues, total agricultural income, and total farm income. Results of the analysis clearly show the importance of rock walls to crop production. In the case of crop revenues, the model has an F-value of 8.01 ($p=0.0055$). The F-statistic level of significance implies that the difference between rock wall adopters and non-adopters in terms of crop revenues is highly significant.

The farming system in Fort-Jacques is intensive with the utilization of improved inputs, such as seeds, fertilizers and pesticides. Run-off may be relatively important on unprotected sloping plots; therefore, the use of expensive inputs on such plots may lead to loss of considerable amount of money. Thus, investments in crop production with the use of costly inputs in Fort-Jacques become attractive once anti-erosive structures are established on plots.

Adoption of rock walls appears also to significantly contribute to total agricultural income which includes crop and livestock revenues. The F-value for this model is 6.73 ($p = 0.0107$), suggesting that adoption of rock walls makes a significant contribution to farmers' agricultural income. According to data collected in the area, the average agricultural income of rock wall adopters represent 1.61 times

that of non-adopters. Those findings show the importance of this soil conservation measure to agricultural production in the Fort-Jacques community.

TABLE 7. EFFECTS OF ROCK WALLS ON HOUSEHOLD INCOME IN FORT-JACQUES, HAITI, 1999

Source	DF	Sum of square	Mean square	F-value	Pr>F
		Crop revenues			
Adoption	1	192832254.45	192832254.45	8.01	0.0055
Error	118	192832254.45	24079120.76		
Total	119	2913772900.4			
		Total agricultural income			
Adoption	1	2259660893.94	2259660893.94	6.73	0.0107
Error	118	2259660893.94	335711564.22		
Total	119	4019547650.60			
		Total farm revenues			
Adoption	1	887216945.89	887216945.89	6.00	0.016
Error	118	1670509677.89	147832829.00		
Total	119	17592326623.79			

Total farm income, comprising agricultural and non-agricultural incomes, appears to be positively affected by the adoption of rock walls. The F-value obtained with this model is 6.00 and the F-statistic is significant at conventional levels. It is clear that adoption of rock walls affect directly and indirectly household total income in Fort-Jacques. In terms of contribution of rock walls to household per capita income, no significant difference is observed. The F-value for this model is 1.76. Even though the level of income is different between the two groups, the distribution of the number of people dependent on the household may average the per capita income at a level that minimizes the difference between adopters and non-adopters.

CONCLUSIONS

Fort-Jacques is considered one of the zones where farmers have historically invested in rock walls without government subsidy. Adoption of this practice, which requires significant cash and labor investments, is influenced by the value of the crops grown in this area and the slope of the land. Encouraging adoption and management of rock walls in Fort-Jacques and surrounding areas is important because of the negative impacts of soil erosion on the environment, and the threat soil erosion represents to downstream villages.

Farmers' behavior toward adoption and management of rock walls in the study area is influenced by social and economic factors. Gender, training in soil conservation, and per capita income are found to be positively and significantly influential in the adoption of rock walls. The results imply that male farmers are more likely to adopt rock walls than females. Also, training in soil conservation practices raises farmers' awareness of the potential damage of soil erosion, and consequently positively affects the adoption of conservation measures. Nonetheless, implementation of rock walls is cash demanding. Farmers with higher per capita income seem to be more likely to invest in rock walls than low-income farmers.

Larger farms and group membership inhibit the adoption of rock walls as evidenced by the negative sign of the coefficients. Limited resource farmers, whose survival depends on the piece of land they operate, are more likely to adopt rock walls because less cash is needed to protect a small farm than a larger one.

It is obvious that rock walls are very important to small-scale farmers in Fort-Jacques. A number of farm operators have established rock wall structures on their plots to facilitate the production of vegetable crops. Management of rock walls differs from one farm to another. The study shows the importance of socioeconomic factors in farmers' decisions to adopt and manage rock wall structures. Given the nature of the farming systems in the region and the characteristics of the rock wall technology, external factors not included in the study may have significant impacts on investment decisions. Farmers may be well aware of erosion problems, but are not willing to adopt sustainable practices in the absence of appropriate incentives; thus, it is important to develop policies that encourage profitable investments in soil conservation practices. Improvement of the market channels for both inputs and outputs of the main vegetable crops produced in the area may be an important step toward encouraging the adoption of rock walls in Fort-Jacques.

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